1.   Introduction

1.1.   Pavement Design Focus

The pavement design process as it is presented in this manual is narrowly defined. It consists of determining whether a proposed layered assemblage of materials (the pavement structure) will adequately perform if subjected to a specified number and intensity of vehicle load cycles. This process is often termed pavement thickness design because the designer usually starts by defining each layer of a candidate pavement structure using known material properties and an assumed layer thickness. The designer then calculates whether the pavement structure will withstand the required vehicle loadings (design loadings).

This manual addresses the design of flexible pavements, i.e., those having an asphalt concrete surface. These methods cannot be used for designing pavement structures surfaced with rigid Portland cement concrete. In the simplest pavement designs, asphalt concrete will serve as only the topmost material layer of the pavement structure. In more complex designs, asphalt concrete will often be used as an overlay layer for existing pavements and/or in the form of an asphalt-treated base course.

As a stand-alone tool, this manual and computer program combination will not turn the neophyte engineer into a pavement design expert. Other engineering skills are needed as well, and many aspects of the general pavement design process are covered minimally or not at all here. The expert pavement designer will have accumulated expertise in economic analysis; construction methods; materials science, including laboratory test procedures and test-data interpretation; hydrology; geological and engineering evaluation of aggregate sources; and asphalt concrete and asphalt cement technology.

The designer must realize that poor foundation conditions and other geotechnical problems can profoundly affect the performance of pavement, regardless of the quality of the pavement thickness design—and often to a far greater extent than the thickness design itself. The pavement designer must therefore actively seek help from technical specialists. Design measures that tackle drainage problems, foundation problems, sloping stability, and erosion usually require consultation with the Regional Materials Section. Regional Materials personnel will also help with designs that must address special Alaska problems such as ice-rich permafrost, muskeg, and with the associated use of special materials such as insulation and geotextiles.

1.2.   Background

Before creating the AKFPD computer program covered in this manual, Alaska DOT&PF used three separate computer programs for designing pavement layer thicknesses for asphalt pavement structures. One of the older programs (AKPAVE98) covered layer thickness design by Alaska's empirically developed "excess fines" method. The two other computerized methods, PAVEINFO and AKOD98, were used for calculating pavement design thickness using what are considered the more advanced methods of mechanistic design (based on layered elastic theory). As two of the program titles indicate, the last significant program updates were in 1998.

Until the AKFPD program and manual became available, the most complete and continually updated source of pavement thickness design information was contained in the *Alaska Preconstruction Manual,* Chapter 11, Section 1180 (Pavement Design). **This manual contains most items of pavement design technology and policy previously covered in the *Preconstruction Manual*.**

During the late 1970s and early 1980s, the State of Alaska began almost simultaneous development of two quite different methods of doing thickness design for asphalt concrete pavements. Today the two design methods are commonly referred to as

- the excess fines design method and

- the mechanistic design method.

Although it is now considered to have limited usefulness, the excess fines method's easily understood concepts and simple computations made it the favorite tool for designing highway pavements since its 1983 adoption by the department. Limitations are inherent because the excess fines method was empirically derived using only highway data. Therefore, the excess fines method cannot be used for designing aircraft runway pavement structures (or any other pavement structures for that matter) that will be subjected to other than normal highway vehicle loadings. Because of its empirical origin, the excess fines method cannot be applied to designing pavement structures that will contain unusual materials. This includes any materials other than the standard road-building types similar to those that characterized the original database.

On the other hand, the mechanistic method is capable of easily handling a huge variety of material types and vehicle load configurations and is the method of choice for designing overlays of existing pavements. DOT&PF officially recognizes mechanistic design as not only the more comprehensively useful tool but as the more defensibly "correct" of the two analytical methods. For some time DOT&PF has required that designs using the excess fines method be checked using mechanistic methods whenever the design traffic loadings are very high (see Sections 2.2. and 2.3 for policies regarding selection of design method).

The term *mechanistic design* is a generic one, implying that the pavement structure is objectively analyzed as a mechanical system of elastic layers. Be aware that the mechanistic pavement design process could be done in a variety of ways, only one of which has been developed for use in Alaska.

Chapters 3 and 4 cover, in detail, the basics of the excess fines method and mechanistic method, respectively.

Regardless of which design method you use, economics will remain a chief concern. As in any engineering discipline, the pavement design engineer must design a pavement structure that cost-effectively meets the intended need. To do this, the designer must consider life-cycle costs. Life-cycle costs include all costs associated with constructing, maintaining, and rehabilitating the pavement structure through a defined period of service (the analysis period). The Federal Highway Administration (FHWA) recommends a minimum analysis period of 35 years. Economic impact on the public (user costs) must be included in life-cycle cost calculations whenever possible.

1.3.   Introducing an Important Concept: The "Pavement Structure"

Vehicles are not supported by the asphalt concrete surfacing material alone. Much of the support comes from some thickness of bound (asphalt cemented) and/or unbound material under the asphalt concrete surface layer(s). This brings up a few questions: (1) What total thickness of material supports the load? (2) What quality of material is required within this thickness? (3) What happens if poor quality materials are used within this thickness?

The asphalt concrete pavement is the top layer of a pavement structure. Pavement structure is an important concept, defined for our purpose as the total thickness of material that "feels" significant compression stresses (and therefore strain) under the design vehicle's wheel loading, i.e., the material that must support that load. Material at the surface (asphalt concrete surfacing) and material close to the surface (base course) will be subjected to relatively strong compression stresses and therefore high levels of strain. Stresses and strains due to vehicle loadings are distributed laterally within the pavement structure and attenuate quickly with depth. The influence of a standard vehicle loading is attenuated to such a degree that at about 10 feet below the surface, stresses and strains are about zero. A good discussion of stress distribution through uniform and layered soil structures can be found in almost any soils engineering textbook.

The empirically derived rule-of-thumb adopted for use in Alaska is that normal highway loads are carried by the asphalt concrete pavement plus an additional 3.5 feet of layered pavement structural materials. Alaska's

excess fines design method specifically defines the pavement structure based on this rule-of-thumb. The excess fines method therefore requires that all material to a depth of 3.5 feet below the bottom of the asphalt concrete pavement be accounted for in every pavement design analysis. For very heavy design loads, including heavy aircraft, the total thickness of materials influenced significantly by the live load can substantially exceed the 3.5-foot rule-of-thumb, and pavement designs should be done using the mechanistic method because it has no inherent limitations on materials thickness.

Figure 1-1 illustrates how strains are distributed within a typical pavement structure. The required load-carrying capacity of each layer is directly related to the strain contribution of that layer. Layers having the largest strain contributions must therefore be of highest quality (stiffest) in order to minimize pavement bending and resultant damage.

Alaska research strongly suggests that the quality of unbound aggregate materials within the pavement structure is mostly controlled by the percentage of fines (weight percent of particles finer than the #200 sieve, also known as P_{200}, minus 75 micron, or $P_{0.075\,mm}$. The P_{200} content usually controls the aggregate's ability to support vehicular load, especially during the springtime thaw period. The general relationship is low P_{200} content = good support and high P_{200} content = poor support. The P_{200} content matters less as depth below the asphalt concrete pavement surface increases. At a depth greater than 3.5 feet, a high P_{200} content is acceptable (assuming standard highway-type loadings).

The geotechnical purist may argue that the minus 0.02 mm (also known as minus 20 micron or $P_{0.02\,mm}$) size fraction, rather than the P_{200} size fraction, controls freeze/thaw-related seasonal aggregate strength characteristics. The relationship between frost susceptibility of materials (therefore thaw-weakening) and $P_{0.02\,mm}$ derives from A. Casagrande's early research into the frost heave phenomena[1] determined that soils containing less than 3% $P_{0.02\,mm}$ are usually non-frost-susceptible (NFS). Since the 1970s, DOT&PF engineers have adopted their own NFS criterion, and DOT&PF recognizes P_{200} content as a useful indicator of frost susceptibility for pavement design purposes. DOT&PF now classifies most natural soils and manufactured aggregates containing $\leq 6\%$ P_{200} as NFS.

Interestingly, gradation data from many Alaska soils and aggregates indicates that the $P_{0.02mm}$ content usually runs approximately half the P_{200} content. It is therefore no surprise that material containing 6% or less P_{200} (therefore likely containing 3% or less $P_{0.02mm}$) should be classified as NFS. The question remains: If the original Casagrande criterion successfully defines the NFS condition, why has DOT&PF chosen to rely on the P_{200} content? The reason is that it is much easier to measure the P_{200} content of a sample (requires only sieve analysis) than it is to measure the $P_{0.02\,mm}$ content (requires hydrometer analysis).

Depending on traffic intensity, weather, and groundwater level, excess P_{200} will cause springtime softening in layers supporting the asphalt concrete pavement. If softening occurs, visualize the situation as a cracker (the asphalt concrete pavement) on a thick layer of cream cheese—the pavement is unsupported and highly vulnerable to imposed vehicle loads under these conditions.

Figure 1-1. Strain Distribution With Depth
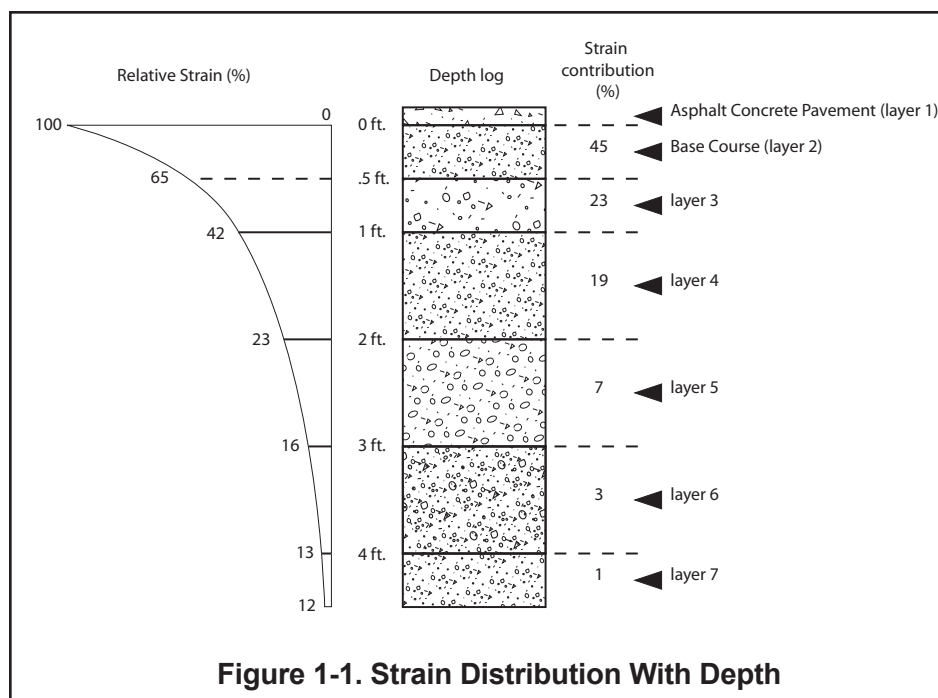
1.3.1 Characterizing Materials Within the Pavement Structure as Input for the AKFPD Program

This manual provides the designer with methods for determining the thickness of pavement structural layers in new construction projects and overlay for pavement rehabilitation projects. Design procedures presented here require design inputs that accurately represent real loadings and materials conditions. Considerable engineering judgment is required to properly select design inputs.

The excess fines design method handles P_{200} content in a very direct way. It uses the P_{200} content of each unbound aggregate layer as an item of input data.

The mechanistic method does not handle the P_{200} content of individual aggregate layers directly. Instead, aggregate layers are characterized in terms of their elastic properties. Specifically, these properties are repeated-load, i.e., "dynamic" elastic modulus (a measure of stiffness called resilient modulus and noted by the symbol "M_R") and Poisson's ratio (deformational characteristic, noted by the symbol "μ"). M_R is defined in Section 4.3.1 where program input values are discussed in detail.

For designing most new pavement structures, mechanistic properties of the various layers are often obtained from DOT&PF-approved tables. These tables provide reasonably accurate estimates of mechanistic properties for aggregate materials based on P_{200} content. These tables are presented with supplementary information in Chapter 5.

Values for M_R can also be obtained through laboratory testing or through the process of "backcalculation," using data collected in the field by deflection testing equipment. Derivation of mechanistic properties from laboratory tests and backcalculation is applicable mostly to the design of overlays for existing pavements. Laboratory test methods recommended for determining the M_R values of asphalt concrete and soil/aggregate materials are, respectively, ASTM D4123-82 and AASHTO T 292-97 (2000). Chapter 5 presents summaries of M_R test methods for asphalt concrete and soils/aggregates. Chapter 5 also presents an overview of the extensive field testing and other requirements associated with the process of backcalculating M_R values. Detailed explanation of the backcalculation process is far outside the scope of this manual.